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ABSTRACT: A high-speed recognition scheme applicable to the automatic extraction of craters of arbitrary sizes from remotely-sensed images has been devised. A high-speed algorithm with low computational load are two of the key requirements for an effective machine vision solution for the shape estimation of small bodies. In this paper, a massively-parallel scheme which is effective for high-speed shape recognition is proposed, and the results of experiments using various shapes in simulated images are shown.

INTRODUCTION: In the autonomous exploration of space resources, it is anticipated that machine vision will be one of the vital technologies for the automatic estimation of the shapes and sizes of small bodies and craters. In particular, remotely-sensed images from spacecraft give us a wealth of information about the shapes of structures on celestial bodies, and many image analysis methods, including image recognition, have been studied to analyze them. In precise recognition schemes, however, there is an inevitable problem of with processing time; that is, although the processing carried out on each pixel in the image is not complex, this processing must be applied to the huge number of pixels comprising the whole image. Thus, computational load becomes enormous and execution becomes difficult on ordinary computers.

Various methods to achieve high-speed processing have been reported, hierarchical processing being among effective methods [1]. In the construction of a hierarchical image data structure, however, it is not easy to overcome the discontinuities of contours of the shapes in celestial images resulting from the imaging sensor elements or system noise. This results in reduced processing efficiency and so increases the complexity of the shape recognition. To address these problems, we have developed an advanced high-speed process using massively-parallel processing.

PARALLEL METHOD FOR RECOGNITION: In machine vision, various types of pattern recognition algorithms have been studied. The mapping algorithm, of which the Hough transform [2] widely used in detecting line segments is a representative example, is one of the more powerful tools.

This algorithm can be extended to the recognition of other shapes [3]. In the recognition of craters on the surface of celestial bodies, quadratic shapes such as circular structures (Eq.1) and elliptical structures (Eq.2), are expected to be extracted automatically:

$$(x - a_1)^2 + (y - a_2)^2 = a_3^2 \qquad \text{(Eq.1)}$$

$$\{(x-a_1)\cos a_3 + (y-a_2)\sin a_3\}^2 / a_4^2 + \{-(x-a_1)\sin a_3 + (y-a_2)\cos a_3\}^2 / a_5^2 = 1 \qquad \text{(Eq.2)}$$

where the a_i (i = 1,2,..,5) are parameters defining the shapes, and the x, y are positions in the image.

The number of pixels on the outline of the shape in the image space (x,y) is equivalent to the frequency value of the histogram in the parameter space (a_1, a_2,..., a_p: p=3 for a circular shape, p=5 for an ellipse). In building up the histogram, each pixel in the image must be checked to see whether it satisfies the shape equations given by Eq.1 and Eq.2. This process requires lengthy computation in proportion to the image size.

This large computational load is an inevitable obstacle to high speed processing in this shape recognition method. A reasonable solution to this problem is to use massively-parallel processing. In this scheme, the optimal parallel criterion is the equalization of the computational load between each of the node processors (NPs). The basic algorithm is shown in Fig.1, where the number of NPs is set at 16 as an example. The number of divisions of the computational work is optimized according to the number of NPs. In this algorithm, we have used a scheme of massively parallel of memory area for the parameter space instead of image data parallel because of inevitability of detecting maximum histogram in the parameter space (shown in Fig.2).

SIMULATION RESULTS: Experiments have been carried out using a massively-parallel processor machine with 336 node processors. From the trade-off between the optimal number of NPs vs computational time in the massively-parallel processing of elliptical shapes, the effectiveness of this algorithm was verified as shown in Fig.3.

CONCLUDING REMARKS: The proposed scheme in this paper is robust for shape recognition in noisy remotely-sensed images. The parallel scheme with optimum division of the computational load can execute shape recognition effectively and can cope with the problem of high-speed processing, giving the possibility of implementation on on-board processors. In addition, this algorithm has the ability to be extended to the recognition of shapes more complicated than crater-like structures.

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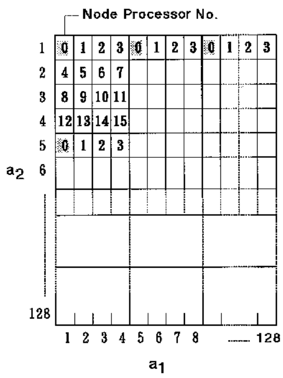

Fig. 1 Basic Massively Parallel Scheme with Load Equalization -Parameter space areas computed by each processor in case of 16 node processors

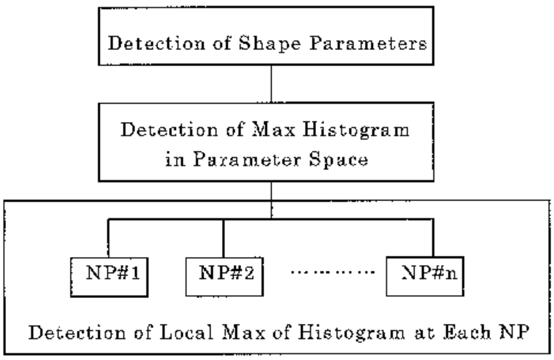

Fig. 2 Shape Parameter Detection Scheme

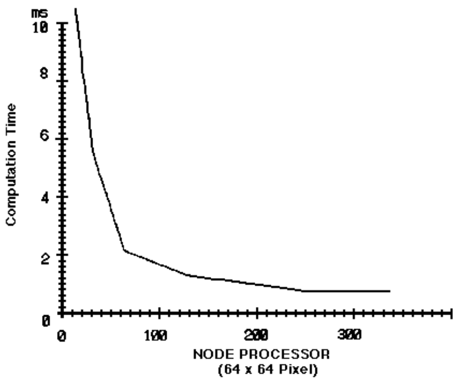

Fig. 3 Computational Load in Crater-like Structures Using the Massively Parallel Processor.